FACTORS AFFECTING THE VITAMIN C CONTENT OF APPLES [1]

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INTRODUCTION

Marked variations in the vitamin C content of different varieties of apples have been observed. The values of 21 Massachusetts-grown varieties were reported by Smith and Fellers,[2] and the results of several other workers have been summarized by Batchelder.[3] Between different lots of apples of the same variety small differences in vitamin C concentration have been found which appeared to result from the kind of fertilizers used (Potter and Overholser).[4] Nelson and Mottern [5] report that the vitamin C content of oranges is low in fruit from trees that have been heavily sprayed with lead arsenate. It seemed possible that the adverse effect of the spraying might have resulted primarily from a lowering of the effective photosynthetic capacity of the leaf.

A change in the ratio of leaf area to fruit, effected by thinning of leaves to produce a low ratio and by thinning of undeveloped fruit to produce a high ratio, would afford a means of measuring directly the influence upon the vitamin C content of fruit of a change in its supply of the products of photosynthesis. Hence, in this investigation of the factors that affect the vitamin C content of apples, a study was made of the concentration of this vitamin in apples grown with a high ratio of leaf area to fruit as compared with apples grown with a low ratio of leaf area to fruit. A study was also made of size of individual apples as a factor in the measurement of the vitamin C content. Two varieties of apple, Delicious and Winesap, were used. Both varieties were grown with different ratios of leaf area to fruit in connection with the experimental work of the Division of Horticulture of the Washington Agricultural Experiment Station at Pullman. Each variety was grown under uniform conditions of fertilization, spraying, and other environmental factors, the sole variant being ratio of leaf area to fruit.

METHODS

Delicious apples of mature trees grown on large, unringed branches were adjusted the first week in July, in one case to an approximate leaf-fruit ratio of 60 leaves to each fruit and in another case to 20

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[2] SMITH, G. G., and FELLERS, C. R. THE VITAMIN C CONTENT OF TWENTY-ONE MASSACHUSETTS GROWN VARIETIES OF APPLES. Amer. Soc. Hort. Sci. Proc. 31: 89–95. 1934.

[3] BATCHELDER, E. L. VITAMIN C IN DELICIOUS APPLES BEFORE AND AFTER STORAGE. Jour. Nutrition 7: 647–655, illus. 1934.

[4] POTTER, M. T., AND OVERHOLSER, E. L. THE VITAMIN C CONTENT OF THE WINESAP APPLE AS INFLUENCED BY FERTILIZERS. Jour. Agr. Research 48: 367–373. 1933.

[5] NELSON, E. M., and MOTTERN, H. H. EFFECT OF LEAD ARSENATE SPRAY ON THE COMPOSITION AND VITAMIN CONTENT OF ORANGES. Amer. Jour. Pub. Health 22: 587–600, illus. 1932.

leaves to each fruit. Winesap apples were grown with similar leaf-fruit ratios, but upon ringed branches.

The apples were stored at 32° F. soon after harvesting, since results obtained the previous season with Delicious apples [6] had indicated that vitamin C is almost completely preserved at this temperature for the length of time covered by these experiments.

The method of vitamin C determination was similar to that hitherto employed in this laboratory, being a modification of the method of Sherman, La Mer, and Campbell.[7] In the first series of experiments, the apples were fed in radial sections.

RESULTS

VITAMIN C CONTENT AS AFFECTED BY RATIO OF LEAF AREA TO FRUIT

The results of the first series of experiments, with Delicious apples, are presented in table 1. Almost no difference was observed between the Delicious apples grown at the high leaf-fruit ratio and those grown at the low. The results obtained with 20 g of Delicious apple in each case corresponded closely with results obtained in earlier work by Batchelder [8] with check Delicious apples at this level. Guinea pigs receiving 23 g showed very slight scurvy, while those receiving 25 g in the previous study were completely protected. Apparently 25 g of Delicious apple represented very nearly the minimum protective dose according to the methods employed, with apples grown under the conditions prevailing in the station orchard. Different results reported from other laboratories may possibly be attributable to differences in size of apples or method of sampling, as later shown.

TABLE 1.—*Antiscorbutic potency of radial sections of Delicious and Winesap apples grown with high and low leaf-fruit ratios when fed to guinea pigs as the sole source of vitamin C*

Vitamin C supplement	Animals	Average daily gain or loss in weight	Average scurvy score
	Number	*Grams*	
Delicious, high leaf-fruit ratio:			
23 g	4	3.8	2.0
20 g	5	2.0	4.4
17 g	5	2.3	6.4
Delicious, low leaf-fruit ratio:			
23 g	6	1.8	2.2
20 g	6	1.7	5.5
17 g	5	1.7	6.2
Winesap, high leaf-fruit ratio: 8 g	8	1.6	9.9
Winesap, low leaf-fruit ratio: 8 g	8	1.8	4.9
Cabbage, 20 g [1]	11	3.1	.5
None [2]	2	−3.7	20.0

[1] Positive controls.
[2] Negative controls.

Contrary to the results obtained with Delicious apples, there was considerable difference between the Winesap apples grown at the two leaf-fruit ratios, those grown at the low ratio having a higher vitamin

[6] BATCHELDER, E. L. See footnote 3.
[7] SHERMAN, H. C., LA MER, V. K., and CAMPBELL, H. L. THE QUANTITATIVE DETERMINATION OF THE ANTISCORBUTIC VITAMIN (VITAMIN C). Jour. Amer. Chem. Soc. 44: 165–172, illus. 1922.
[8] BATCHELDER, E. L. See footnote 3.

C content than those grown at the high ratio. These apparently conflicting results with Delicious and Winesap apples may be explained on the basis of size, since the high- and low-ratio Winesaps showed the marked difference in size usually observed between apples grown under very different conditions; whereas the Delicious apples, presumably because the thinning was not completed sufficiently early and because the apples with the adjusted leaf-fruit ratios were not grown on ringed branches, were nearly the same in size and color, and, according to analyses, similar in chemical composition throughout.

VITAMIN C CONTENT AS AFFECTED BY SIZE OF APPLE

The question why the smaller Winesaps (grown at a low leaf-fruit ratio) were richer in vitamin C than the larger Winesaps (grown at a high leaf-fruit ratio) then presented itself. Theoretically, the size of the apple may cause a considerable difference in the scurvy-preventing action of radial sections of apples, or of apples which have been cored and ground before sampling, because there will, in both cases, be a higher proportion of skin in samples from small apples than in samples from large apples; and the skin is known to be much richer than the pulp in vitamin C.[9] Further study of the possibility that the difference between the vitamin C content of high and low leaf-fruit ratio Winesap apples might result from difference in size alone (the smaller apples showing weight for weight the higher vitamin C content) seemed desirable since otherwise it would apparently be necessary to conclude that the difference between the two types of Winesap was in inverse proportion to the nourishment received, and that the similarity of the two types of Delicious apple resulted from the fact that they were thinned too late and not grown on ringed branches, and hence were actually alike in their nutritive history.

A second comparison was therefore made to determine the effect of size on the vitamin C content of apples as ordinarily sampled. Check Winesap apples, the largest and smallest of the lot, were selected for comparison. Table 2 shows the results of feeding 8-g radial sections of large and small Winesap apples. This level was chosen as being probably slightly below the minimum protective dose and, therefore, capable of disclosing slight differences in vitamin C concentration. The average scurvy score shown by guinea pigs fed 8-g radial sections of large Winesaps (average weight 141 g) was somewhat higher than that of animals fed 8-g radial sections of small Winesaps (average weight 79 g), indicating that the large Winesaps contained, weight for weight, less vitamin C than the small Winesaps. Several guinea pigs refused to eat their apples and only four could be used in averaging the results. While a larger number of tests would have been desirable, the difference both in degree of scurvy and in rate of growth was so consistent that it seems certain that further tests would have strengthened the conclusion that the vitamin C supplied by an 8-g radial section of a large Winesap apple is measurably smaller than that supplied by a similar section of a small apple from the same tree.

[9] FELLERS, C. R., ISHAM, P. D., and SMITH G. G. VITAMIN C DISTRIBUTION IN BALDWIN AND M'INTOSH APPLES. Amer. Soc. Hort. Sci. Proc. (1932) 29: 93-97, illus. 1933.

TABLE 2.—*Antiscorbutic potency of large and of small Winesap apples; of sections containing peel and pulp from Winesap apples grown at high and at low leaf-fruit ratios, and of sections from Winesaps stored at 32° and at at 40° F. for 6 months, when fed to guinea pigs as the sole source of vitamin C*

Vitamin C supplement	Animals	Average daily weight gain	Average scurvy score
	Number	*Grams*	
LARGE AND SMALL WINESAP APPLES; 8-G PORTIONS			
Large Winesap	4	0.7	12
Small Winesap	4	1.6	9
SECTIONS CONTAINING PEEL PLUS ONE-FOURTH INCH OF UNDERLYING PULP FROM WINESAPS GROWN AT HIGH AND LOW LEAF-FRUIT RATIOS; 8-G PORTIONS			
Winesap, high leaf-fruit ratio	5	1.1	5
Winesap, low leaf-fruit ratio	6	2.1	4
RADIAL SECTIONS OF WINESAPS STORED AT DIFFERENT TEMPERATURES FOR 6 MONTHS; 10-G PORTIONS			
Winesaps stored at 32° F	5	1.5	6
Winesaps stored at 40° F	8	.3	11

VITAMIN C CONTENT AS AFFECTED BY RATIO OF SKIN TO PULP

A direct comparison of the vitamin C content of the skins of the two types of Winesaps presented difficulties in sampling because of the impracticability of completely removing adhering pulp. On the other hand, direct comparison of the pulps presented difficulties because of the large size of the sample required and the refusal of the guinea pigs to eat a sufficient quantity of the pulp. A method of sampling was therefore devised by which both difficulties were minimized. Table 2 gives the results of a comparison of high and low leaf-fruit ratio Winesaps sampled in such a way that the proportion of skin and pulp was the same for both the large and the small apples. The apples were so sampled that each section of skin had one-quarter inch of pulp attached. The curve of the outer skin was followed in cutting the pulp so that the resulting samples from large apples or from small apples consisted of pulp and skin in similar proportions. While variations in the amount of pulp included in each sample were not completely eliminated by this method of sampling, the variations represented a much smaller percentage of the total weight of the sample and caused a much smaller error in the apparent vitamin C content. The average weight of the high-ratio apples fed was 175 g, and that of the low-ratio apples 90 g. The average scurvy scores for animals fed 8 g of apple sampled as described above was five for the high-ratio and four for the low-ratio apples. These values indicated that, when ratio of skin to pulp was taken into account, the same concentration of vitamin C was present in the tissues of apples grown under widely different leaf-fruit ratios. For the reasons mentioned above, separate tests for pulp and skin were not attempted in connection with this study, but it may be inferred from the foregoing results that the concentration of vitamin C was similar for similar tissues of both large and small apples.

VITAMIN C CONTENT AS AFFECTED BY STORAGE OF APPLES AT 32° AND 40° F. FOR 7 MONTHS

Table 2 also gives the vitamin C value of Winesap apples held at 32° and 40°F. for 6 months. Apples of medium size (average weight 110 g.) were fed in 10-g radial sections. Apples stored at 32° produced only mild scurvy (average score 6), while those stored at 40° produced moderate scurvy (average score 11). Apparently the vitamin C content was better conserved at 32° than at 40°. Comparable results for these apples before storage were not available so that definite conclusions cannot be drawn as to the loss, if any, of vitamin C during 6 months' storage at 32°. Previous work, summarized by Batchelder,[10] indicated that 10 g of Winesap apples completely protected guinea pigs from scurvy. But possible differences in the size of the apples, fertilization of the trees, and other factors make direct comparisons of the vitamin C value of the stored apples reported here with that found in previously reported experiments on freshly harvested Winesaps, inadvisable.

SUMMARY AND CONCLUSIONS

The vitamin C content of apples was studied with respect to the effect of (1) the ratio of leaf area to fruit; (2) the size of fruit as it affected the ratio of skin to pulp, by various methods of sampling; and (3) storage at 32° and 40° F. for 6 months. It was concluded that the ratio of leaf area to fruit affected the vitamin C content of apples only indirectly, i. e., as it affected the size of the fruit produced; that the size of the fruit was an important consideration under common methods of sampling because the ratio of skin to pulp was higher in small apples than in large apples, and the skin contained a higher concentration of vitamin C than the pulp; that storage at 40° resulted in greater loss of vitamin C than did storage at 32°; and that the vitamin C content of Delicious apples in the present study corresponded closely with values hitherto reported from this laboratory.

[10] BATCHELDER, E. L. See footnote 3.